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(54) **SYSTEMS AND METHODS FOR SURGICAL NAVIGATION WITH A TRACKER INSTRUMENT**

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A61B 5/06	(2006.01)
A61B 17/17	(2006.01)
G06T 7/70	(2017.01)

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(58) **Field of Classification Search**
CPC A61B 34/20; A61B 2034/2055; A61B 2034/107; A61B 2034/2074; A61B 5/061; A61B 5/065; A61B 8/42
See application file for complete search history.

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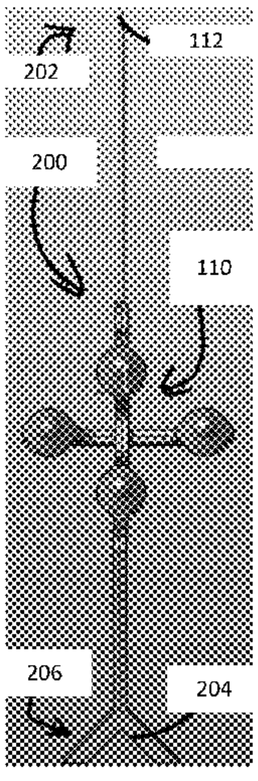
Primary Examiner — Gerald Johnson

(57) **ABSTRACT**

There is provided a surgical instrument for navigated surgeries and systems and methods using such a surgical instrument. The surgical tool comprises a tip; a tool interface, separate from the tip; and an optically trackable target. The tip is configured to probe positions in a space and identify the positions using optical information from the optically trackable target. The tool interface is configured to mate with a surgical tool such that the optical trackable target then provides optical information with which to determine positional information for the surgical tool in the space. In one example, the system provides navigational information during surgery using the surgical instrument, namely, a single integrated tracker instrument with two or more mechanical interfaces for coupling the tracker instrument with anatomical features and/or surgical tools.

16 Claims, 7 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/512,127, filed on May 29, 2017.

(51) **Int. Cl.**

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A61B 17/15	(2006.01)
A61B 34/30	(2016.01)
A61B 90/00	(2016.01)

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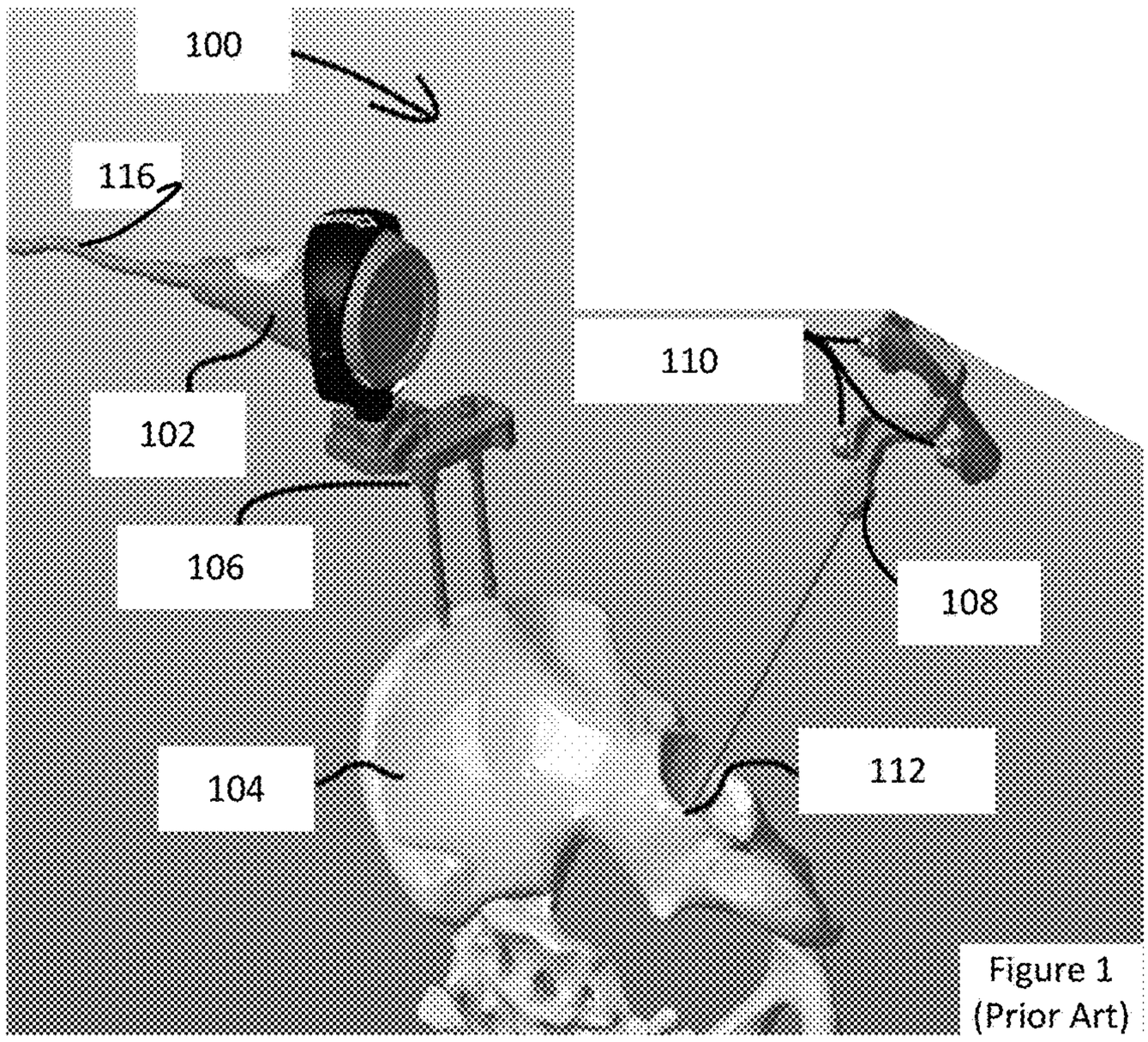


Figure 1
(Prior Art)

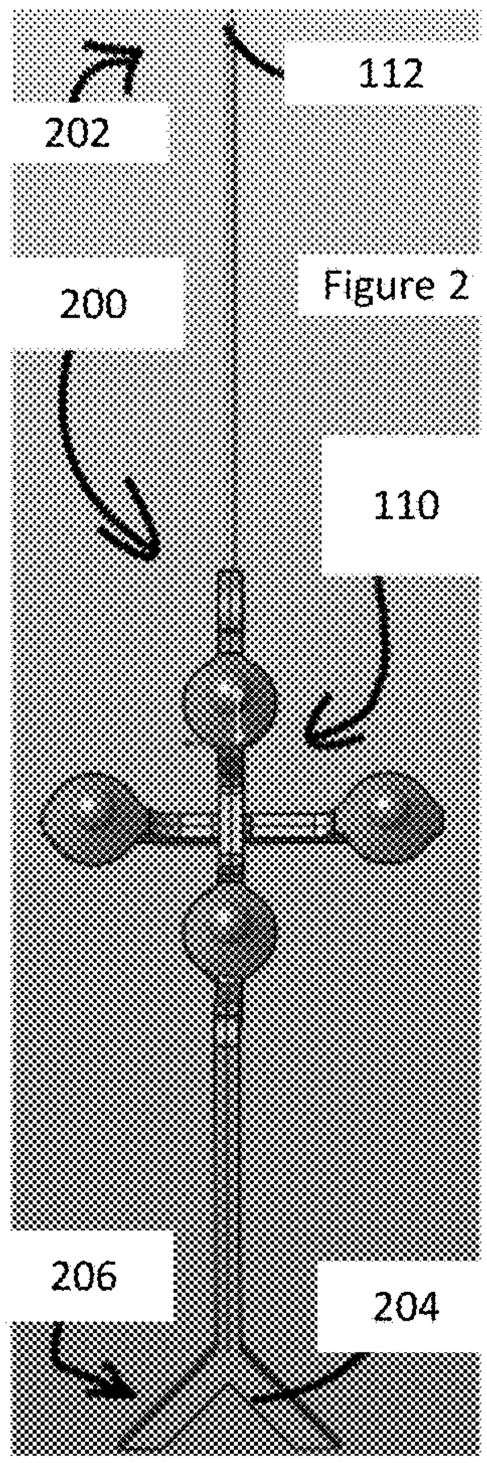


Figure 2

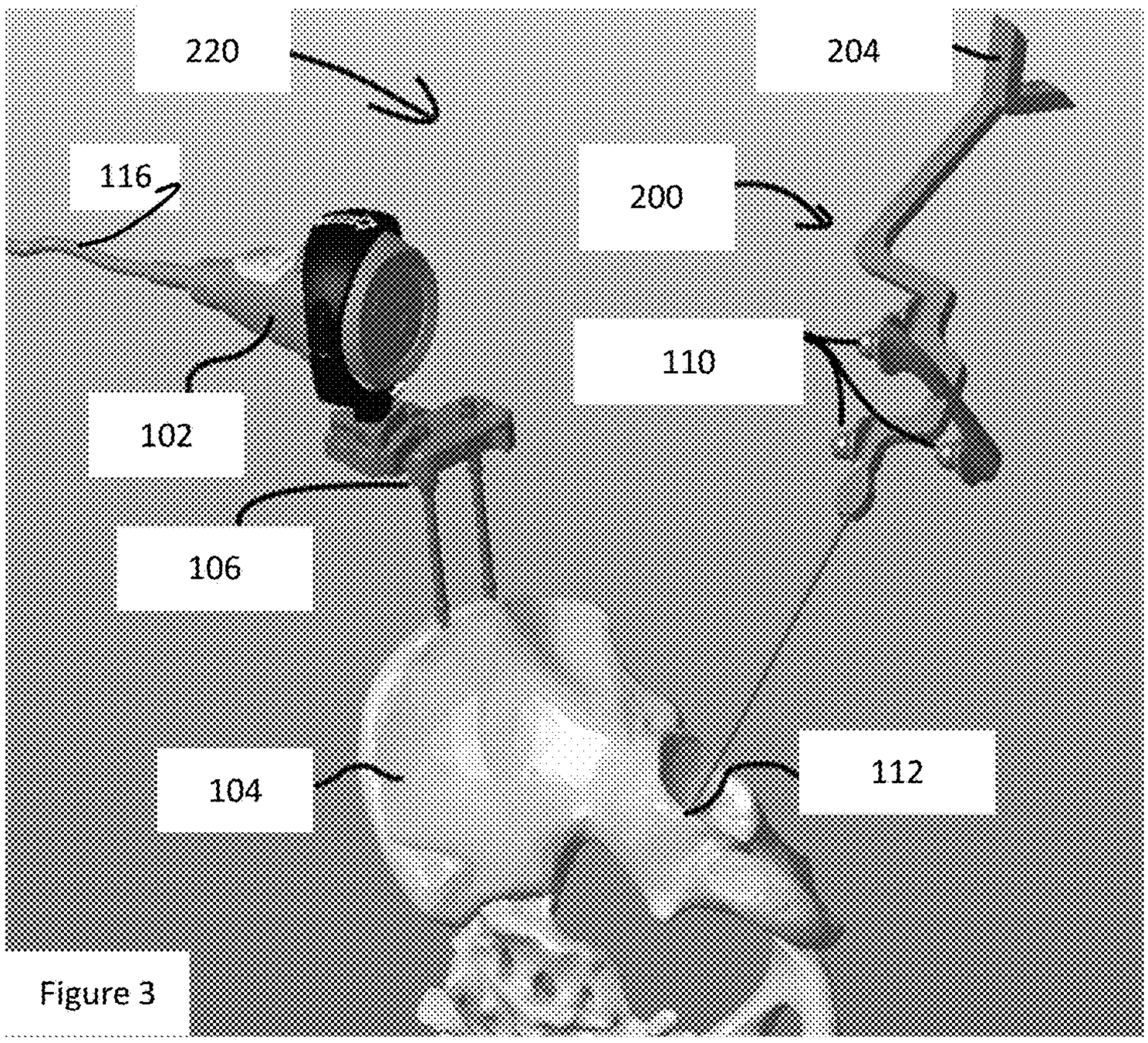
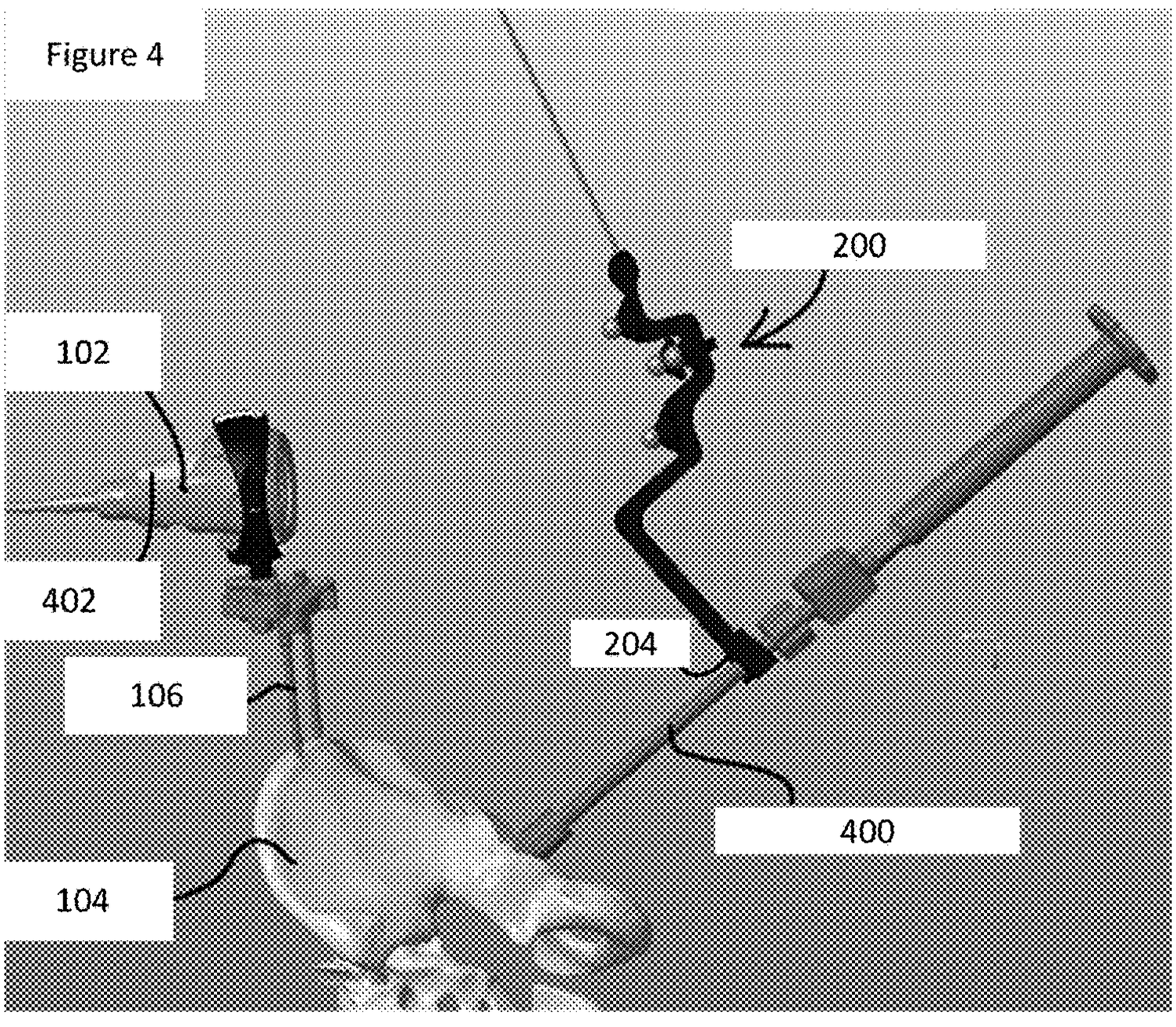


Figure 3

Figure 4



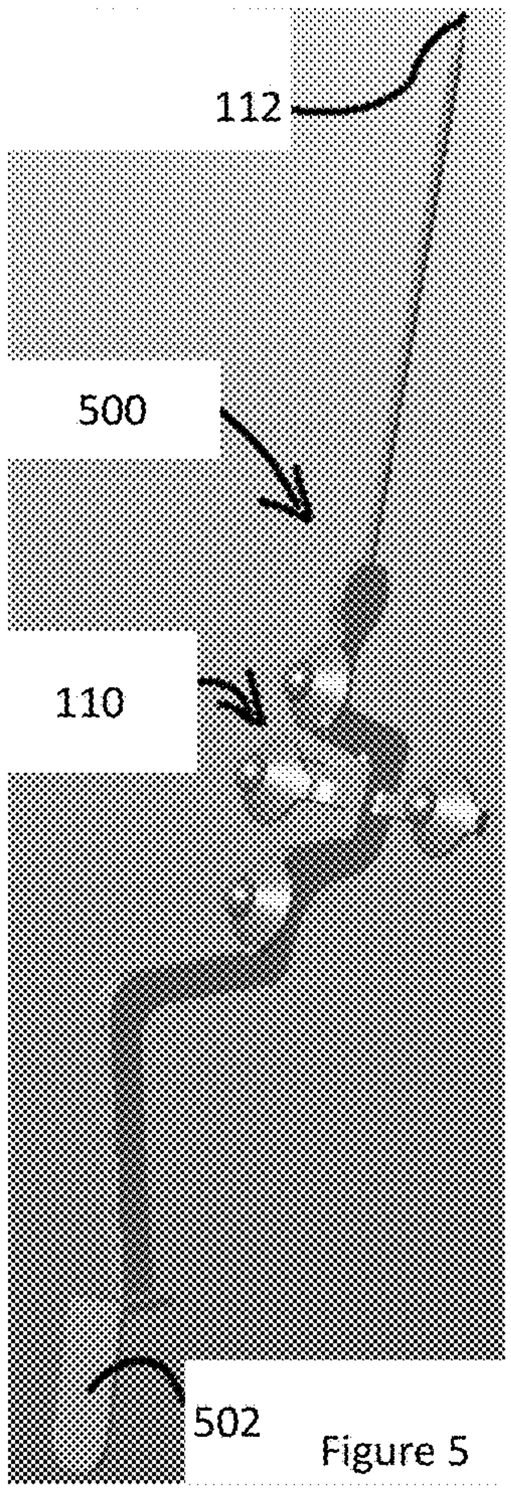


Figure 5

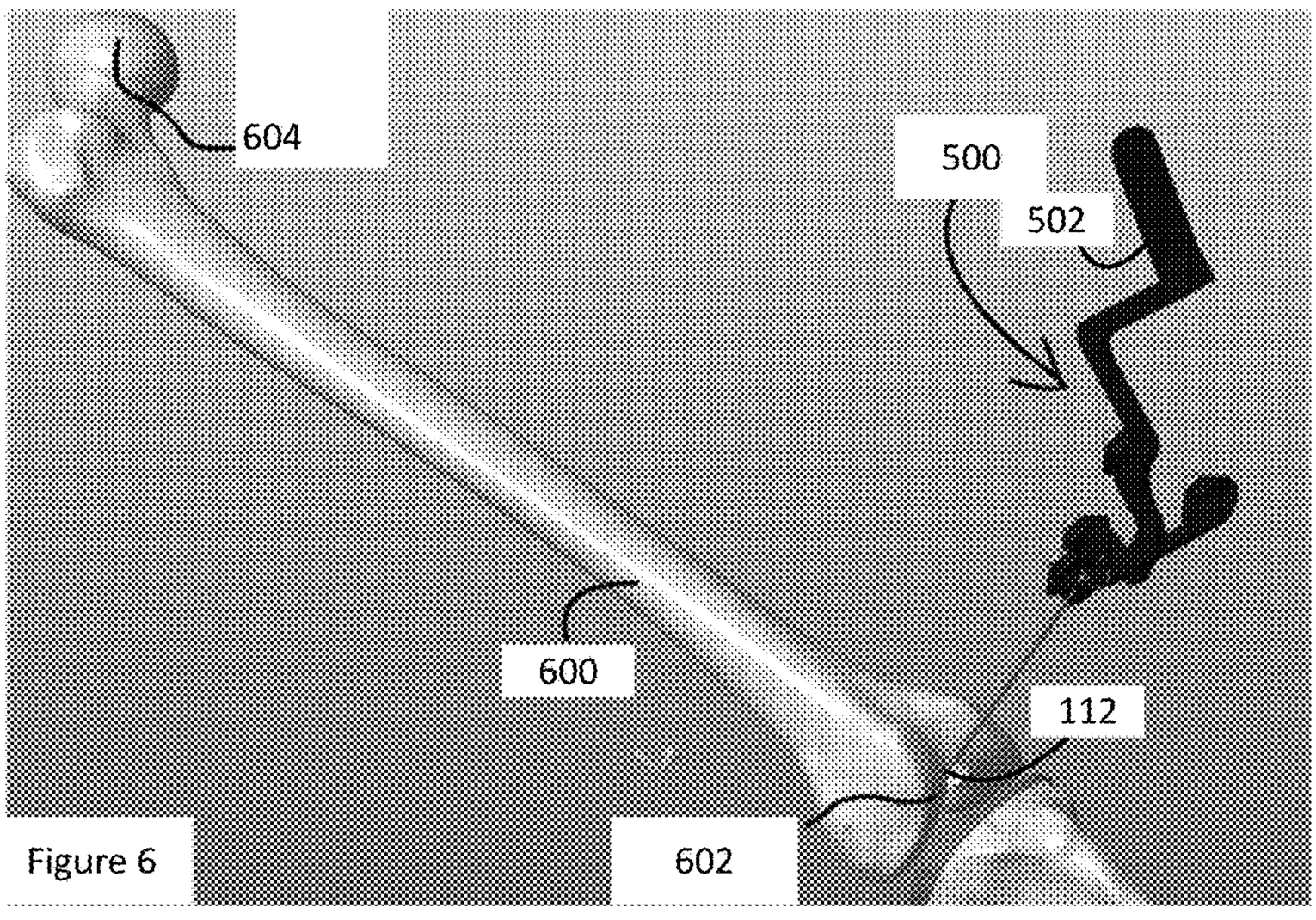


Figure 6

Figure 7

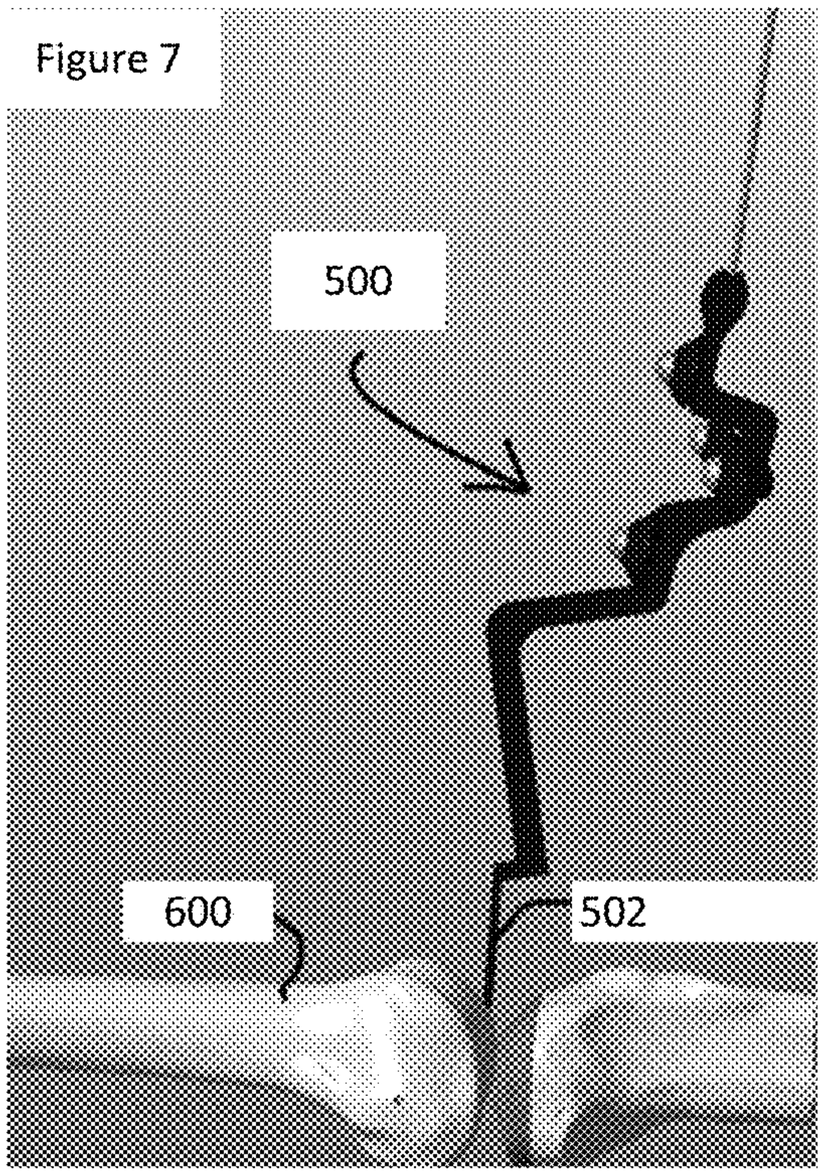
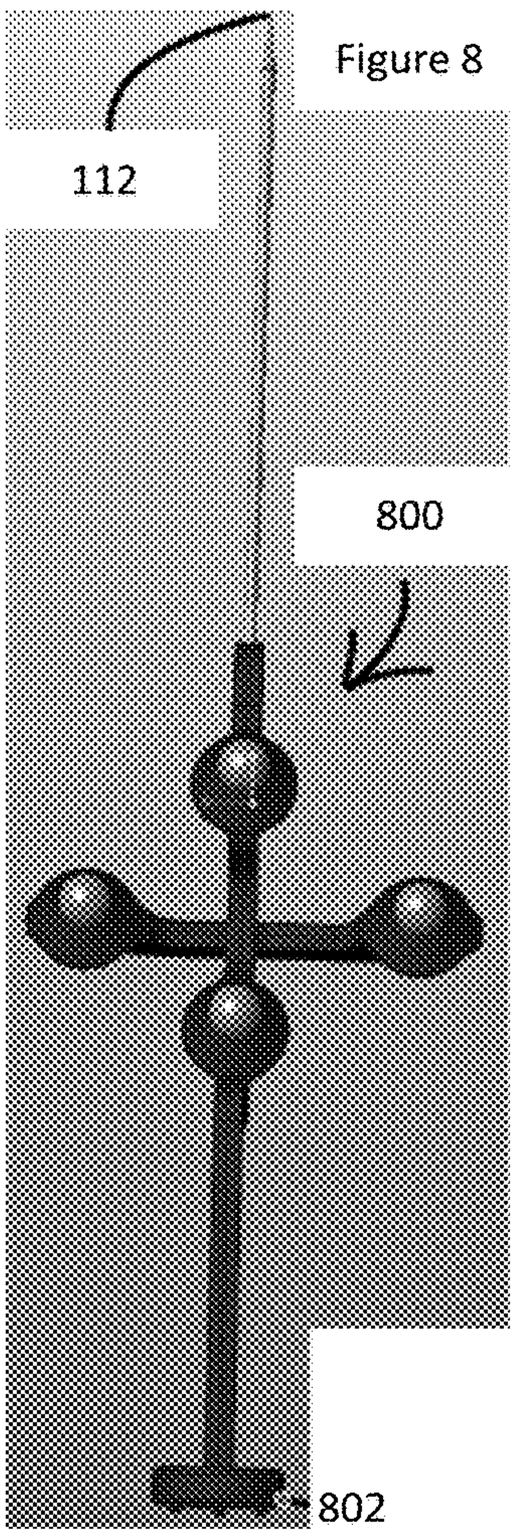


Figure 8



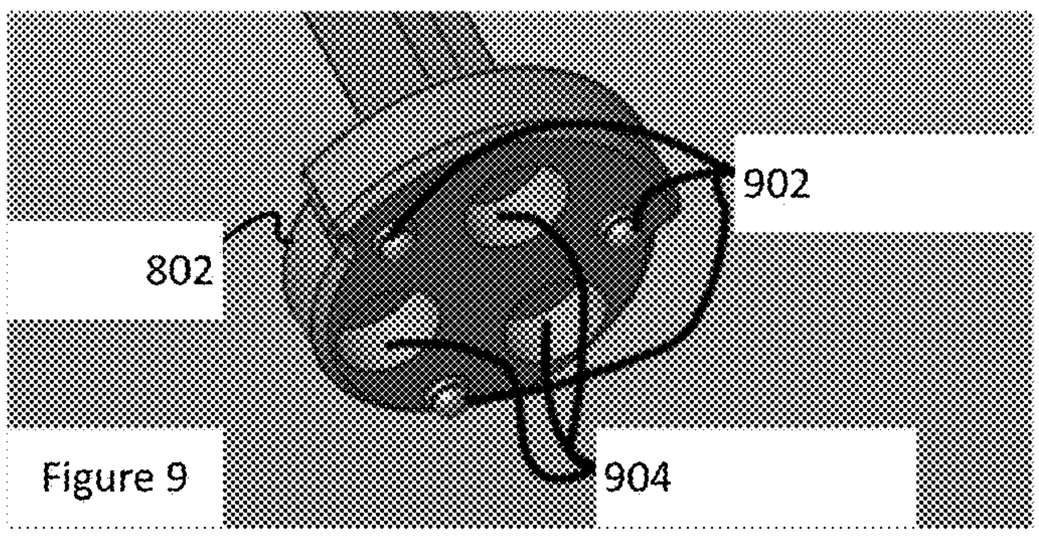


Figure 9

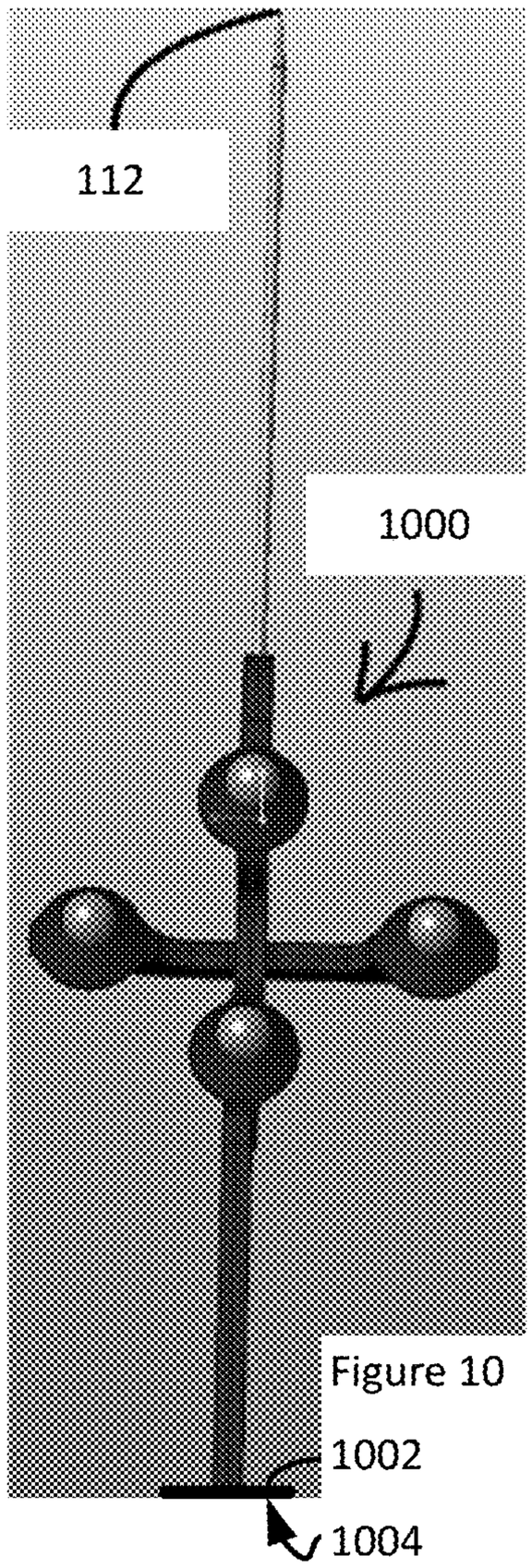


Figure 10

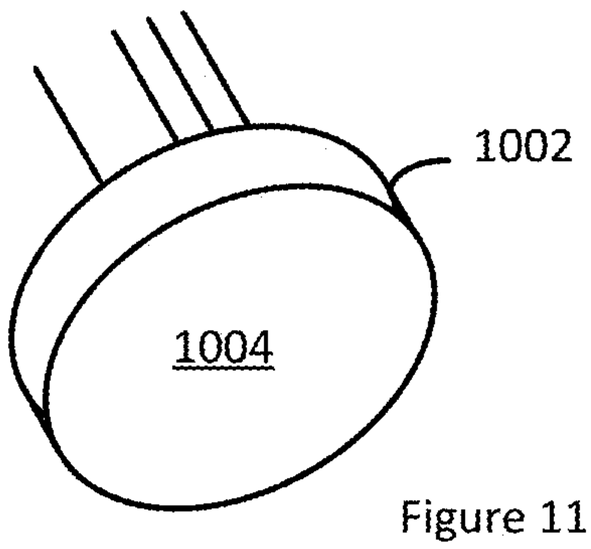


Figure 11

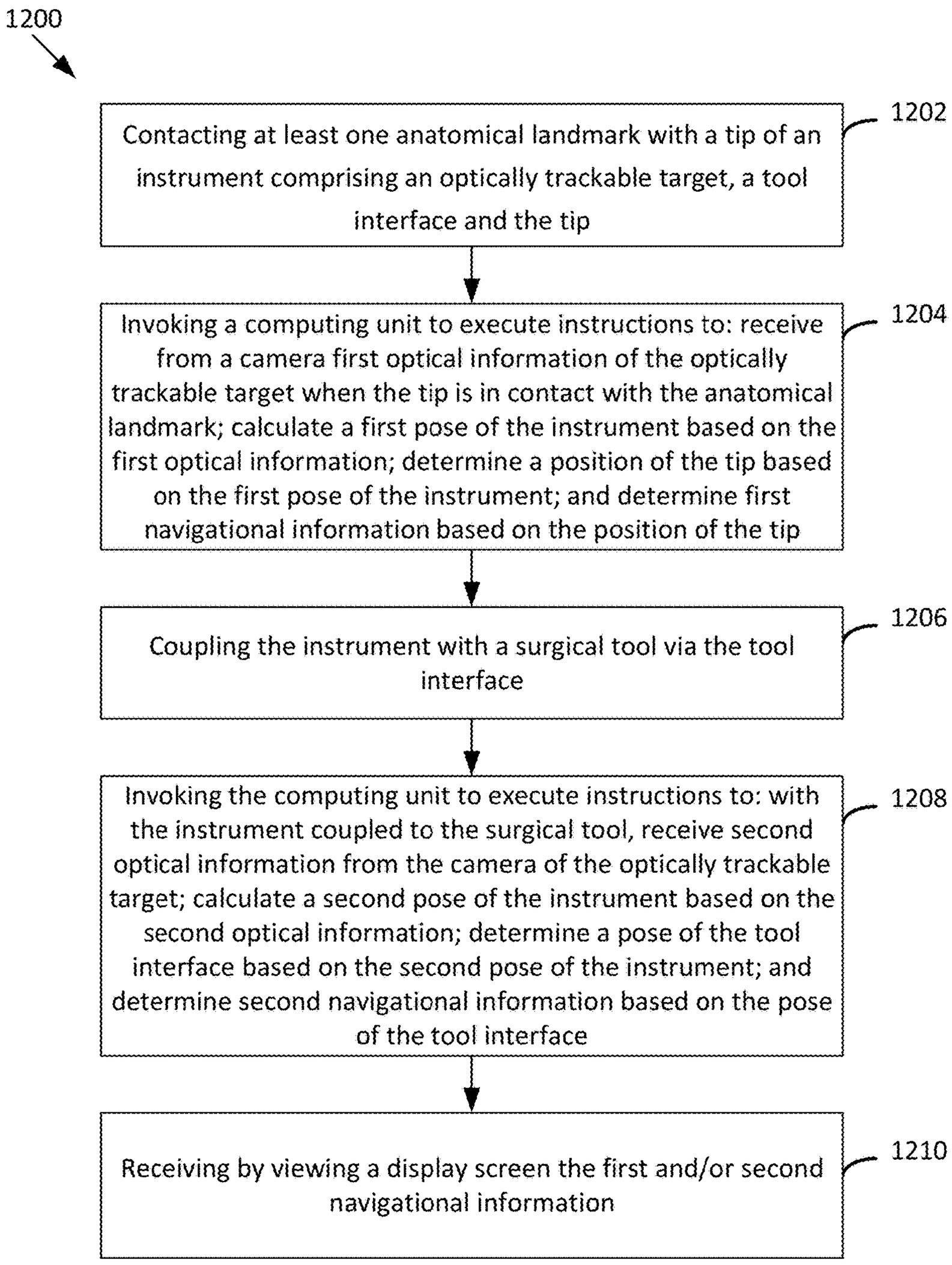

1200
Contacting at least one anatomical landmark with a tip of an instrument comprising an optically trackable target, a tool interface and the tip
1202
Invoking a computing unit to execute instructions to: receive from a camera first optical information of the optically trackable target when the tip is in contact with the anatomical landmark; calculate a first pose of the instrument based on the first optical information; determine a position of the tip based on the first pose of the instrument; and determine first navigational information based on the position of the tip
1204
Coupling the instrument with a surgical tool via the tool interface
1206
Invoking the computing unit to execute instructions to: with the instrument coupled to the surgical tool, receive second optical information from the camera of the optically trackable target; calculate a second pose of the instrument based on the second optical information; determine a pose of the tool interface based on the second pose of the instrument; and determine second navigational information based on the pose of the tool interface
1208
Receiving by viewing a display screen the first and/or second navigational information
1210

Figure 12

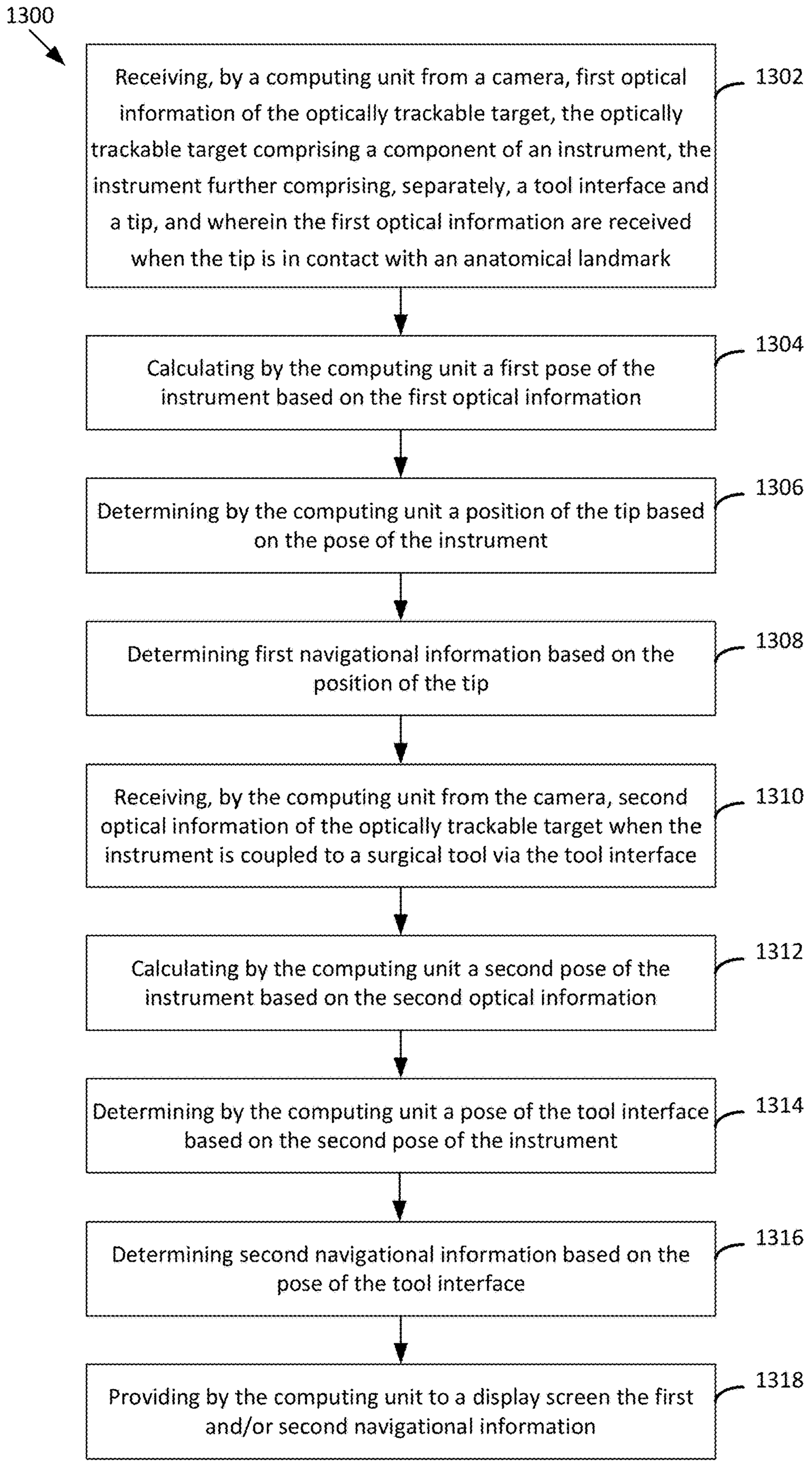

1300
Receiving, by a computing unit from a camera, first optical information of the optically trackable target, the optically trackable target comprising a component of an instrument, the instrument further comprising, separately, a tool interface and a tip, and wherein the first optical information are received when the tip is in contact with an anatomical landmark
1302
Calculating by the computing unit a first pose of the instrument based on the first optical information
1304
Determining by the computing unit a position of the tip based on the pose of the instrument
1306
Determining first navigational information based on the position of the tip
1308
Receiving, by the computing unit from the camera, second optical information of the optically trackable target when the instrument is coupled to a surgical tool via the tool interface
1310
Calculating by the computing unit a second pose of the instrument based on the second optical information
1312
Determining by the computing unit a pose of the tool interface based on the second pose of the instrument
1314
Determining second navigational information based on the pose of the tool interface
1316
Providing by the computing unit to a display screen the first and/or second navigational information
1318

Figure 13

SYSTEMS AND METHODS FOR SURGICAL NAVIGATION WITH A TRACKER INSTRUMENT

CROSS-REFERENCE

The present application is a divisional application of U.S. application Ser. No. 15/991,334 filed May 29, 2018, the entire contents of which are incorporated herein by reference. U.S. application Ser. No. 15/991,334 claims the benefit of U.S. Provisional Application No. 62/512,127 filed May 29, 2017.

FIELD

The present application relates to surgery systems and more particularly to systems and methods for surgical navigation with a tracker instrument.

BACKGROUND

Navigated surgical procedures may rely on identifying anatomical landmarks using the tip of a probe (e.g., for anatomical registration). Navigated surgical procedures may rely on measuring the relative pose of a surgical tool (such as an acetabular cup insertion tool or a cutting guide slot) and a patient's anatomy, and providing navigational information based on the relative pose for display to an operating surgeon, or to a robotic control system for controlling a surgical robot.

There are several modalities for surgical navigation systems, including optical (monocular), optical (stereoscopic), inertial and electromagnetic. FIG. **1** (Prior Art) illustrates an exemplary surgical navigation system **100** comprising a reference element **102** (a camera) mounted to a pelvis **104** via bone fixation hardware **106**, and an instrument **108** (aka a "tracker" or "tracker instrument") comprising an optically trackable target **110** (a constellation of reflective spheres). This instrument may have probe tip **112** such as for pointing to landmarks. A computing unit, not shown, is communicatively coupled to the camera (e.g. via cable **116** or by other manners (e.g. wirelessly) and receives optical information (e.g. signals representing an image) from the camera of the optically trackable target. The computing unit processes the optical information, for example, using image processing operations, computational optimizations and spatial transformations, to provide real-time pose measurements of the instrument such as via display to a display unit (not shown). The computing unit further determines navigational information based on the pose measurements, and provides the navigational information for display or to a robotic control system. Alternatively, the computing unit may save navigational information in memory, and access this navigational information later in the procedure, for example, to generate further navigational information. The computing unit may execute a software workflow that corresponds to the surgical workflow. For example, the software workflow may comprise a series of steps.

The navigational information is spatial information that is directly or indirectly clinically relevant. For example, the navigational information may be: the position and/or orientation of an implant relative to a patient's anatomy; spatial characteristics of a patient's pre- and/or post-surgical anatomy; the position and/or orientation of a surgical tool relative to a patient's anatomy (e.g. the location of the probe tip). In many surgical procedure methods, different navigational information is important during different steps (i.e. the same surgical procedure may have at least two steps, in which different navigational information is important at that step). For example, in one step of a total hip arthroplasty, an acetabular cup is inserted. During this step, the orientation of the acetabular cup relative to patient planes is important navigational information. In another step, a femoral prosthesis is selected and implanted; during this step, the change in the patient's leg length is important navigational information.

Surgical procedures benefiting from different navigational information during different surgical steps may require a dedicated tracker for each step, or may require reconfiguration of a tracker for each step (e.g. attachment/reattachment of a tracker to different surgical tools). In either case, the cost and/or complexity of such systems is high.

SUMMARY

There is provided a surgical instrument for navigated surgeries and systems and methods using such a surgical instrument. The surgical tool comprises a tip; a tool interface, separate from the tip; and an optically trackable target. The tip is configured to probe positions in a space and identify the positions using optical information from the optically trackable target. The tool interface is configured to mate with a surgical tool such that the optical trackable target then provides optical information with which to determine positional information for the surgical tool in the space. In one example, the system provides navigational information during surgery using the surgical instrument, namely, a single integrated tracker instrument with two or more mechanical interfaces for coupling the tracker instrument with anatomical features and/or surgical tools.

In one aspect, there is a surgical instrument comprising: a tip; a tool interface, separate from the tip; and an optically trackable target; wherein the tip is configured to probe positions in a space and the optically trackable target is configured to provide optical information with which to determine the positions; and wherein the tool interface is configured to mate with a surgical tool such that the optical trackable target then provides optical information with which to determine positional information for the surgical tool in the space.

The tip and the tool interface may be located at opposite ends of the instrument. The optically trackable target may be located between the opposite ends.

The tool interface may be one of: a V-channel mounting interface; a kinematic mount; a planar feature without a magnet; and a planar feature with a magnet.

In one aspect there is provided a system to provide navigational information during a surgery comprising: an instrument comprising: a tip; a tool interface, separate from the tip; and an optically trackable target; a computing unit configured to: receive from a camera optical information of the optically trackable target; calculate a pose of the instrument based on the optical information; determine a position of the tip based on the pose of the instrument; determine first navigational information based on the position of the tip; determine a pose of the tool interface based on the pose of the instrument; determine second navigational information based on the pose of the tool interface; and provide at least one of the first and second navigational information to one or more of: a display unit for displaying to a user, computer memory for storage, and a robotic control system.

The instrument may have two opposite ends, and the tip is on one end, the tool interface is on the other end, and the optically trackable target is between the two ends.

The computing unit may be further configured to determine navigation context information; and provide the at least one of the first and second navigational information based on the navigation context information. By way of example, the computing unit may determine the navigation context information based, at least in part, on the pose of the instrument. By way of example, the computing unit may be configured to execute a software workflow comprising a series of steps, and determine the navigation context information, at least in part, based on a current step in the software workflow.

The tool interface may be one of: a V-channel mounting interface; a kinematic mount; a planar feature without a magnet; and a planar feature with a magnet. The planar feature, whether with or without a magnet, may be configured to mate with a cutting slot of a cutting guide.

The computing unit may be further configured to determine the position of the tip and/or the pose of the tool interface based at least in part on calibration data. By way of example, the calibration data may be stored in memory accessible to the computing unit, and derived from manufacturing specifications of the instrument. By way of example, the calibration data may be determined based on a calibration routine.

The first navigational information may be a limb position change and the second navigational information may be an implant alignment. The surgery may be a hip arthroplasty.

The instrument may be pre-sterilized, single-use and disposable.

The first navigational information may define at least one anatomical axis of a bone and the second navigational information may be the alignment of a bone cutting guide relative to the at least one anatomical axis. The surgery may be a knee arthroplasty.

In one aspect there is provided a system to provide leg position change information and acetabular implant alignment information during a hip arthroplasty surgery on a patient comprising: an instrument comprising a tip, a tool interface separate from the tip, and an optically trackable target; wherein the tool interface is a V-channel to mate with an axis of an acetabular implant inserter tool; and a computing unit configured to: receive optical information from a camera of the optically trackable target; calculate pose information of the instrument based on the optical information; calculate a first position of the tip when in contact with a landmark on a patient's femur, prior to arthroplasty; calculate a second position of the tip when in contact with the landmark on the patient's femur after arthroplasty; determine change in leg position information based on at least the first position and second position; calculate a pose of the tool interface when mated with an acetabular implant inserter tool during acetabular implant alignment; determine acetabular implant alignment information based on at least the pose of the tool interface; and provide leg position change information and acetabular implant alignment information to a display unit.

In one aspect there is provide a system for providing navigational information during a surgery comprising: presterilized, single-use and disposable components including an instrument comprising a tip, a tool interface separate from the tip and an optically trackable target; and a tracking system comprising: a camera to generate optical information of optically trackable targets; and a computing unit configured to execute a computer-implemented workflow corresponding to a surgical workflow and provide navigational information to a display unit based on pose information derived from optical information received from the camera, the camera being communicatively coupled to the computing unit; and wherein the system for providing navigational information is free from any components requiring reprocessing for sterility. The pre-sterilized, single-use and disposable components may further include a drape configured to provide a sterile barrier around the camera, the drape further comprising an optical window to enable the camera to generate the optical information from within the sterile barrier.

In one aspect there is provided A computer implemented method to perform a navigated surgical procedure comprising: receiving, by a computing unit from a camera, first optical information of an optically trackable target, the optically trackable target comprising a component of an instrument, the instrument further comprising, separately, a tool interface and a tip, and wherein the first optical information is received when the tip is in contact with an anatomical landmark; calculating, by the computing unit, a first pose of the instrument based on the first optical information; determining, by the computing unit, a position of the tip based on the first pose of the instrument; determining, by the computing unit, first navigational information based on the position of the tip; receiving, by the computing unit, from the camera, second optical information of the optically trackable target when the instrument is coupled to a surgical tool via the tool interface; calculating, by the computing unit, a second pose of the instrument based on the second optical information; determining, by the computing unit, a pose of the tool interface based on the second pose of the instrument; determining, by the computing unit, second navigational information based on the pose of the tool interface; and providing, by the computing unit, to a display screen the first and/or second navigational information.

In one aspect there is provided A system to provide navigational information during a surgery comprising: an instrument comprising: a tip; a tool interface, separate from the tip; and an optically trackable target; a computing unit configured to: receive from a camera optical information of the optically trackable target; calculate a pose of the instrument based on the optical information; determine navigation context information based on the pose of the instrument; and responsive to the navigation context information, perform one of: A) determine a position of the tip based on the pose of the instrument; determine first navigational information based on the position of the tip; and provide the first navigational information to one or more of: a display unit for displaying to a user, computer memory for storage, and a robotic control system; and B) determine a pose of the tool interface based on the pose of the instrument; determine second navigational information based on the pose of the tool interface; and provide second navigational information to one or more of: a display unit for displaying to a user, computer memory for storage, and a robotic control system.

These and other aspects including related computer implemented method and/or computer readable media aspects will be apparent to those of ordinary skill in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an annotated CAD illustration of components of a surgical navigational system according to the prior art.

FIG. **2** is an annotated CAD illustration of a tracker instrument in accordance with an example having a V-Channel mount as one mechanical interface.

FIG. **3** is an annotated CAD illustration of components of a surgical navigation system including a tracker instrument in accordance with FIG. **2**.

FIG. **4** is an annotated CAD illustration of the surgical navigation system of FIG. **3** with the tracker instrument coupled to an acetabular inserter.

FIG. **5** is an annotated CAD illustration of a tracker instrument in accordance with an example having a planar feature as one mechanical interface.

FIG. **6** is an annotated CAD illustration of the tracker instrument of FIG. **5** coupled to a femur to point to an anatomical landmark thereon, for example, to perform a femur registration.

FIG. **7** is an annotated CAD illustration showing the planar feature of the tracker instrument of FIG. **5** in an alignment with the femur for example for a femur cut.

FIG. **8** is an annotated CAD illustration of a tracker instrument in accordance with an example having a kinematic mount as one mechanical interface.

FIG. **9** is an annotated CAD illustration of details of the kinematic mount of FIG. **8**.

FIG. **10** is an annotated CAD illustration of a tracker instrument in accordance with an example having a planar feature, cylindrical in shape, as one mechanical interface.

FIG. **11** is an illustration showing an enlarged perspective view from an end of the tracker instrument of FIG. **9** showing the planar feature.

FIG. **12** is a flowchart showing a method to perform a navigated surgical procedure according to an example.

FIG. **13** is a flowchart showing a computer implemented method to perform a navigated surgical procedure according to an example.

DETAILED DESCRIPTION

A system for providing navigational information during surgery may provide a single integrated tracker instrument with two or more mechanical interfaces for coupling the tracker instrument with anatomical features and/or surgical tools. For example, as shown in FIG. **2**, a tracker instrument **200** has one mechanical interface that is a probe tip **112** similar to FIG. **1** at a first end **202** used for contacting points in space, such as anatomical landmarks, and another mechanical interface that is a tool interface. In the present example the tool interface is a V-channel **204** (e.g. a V-channel mounting interface) at a second end **206** for coupling to the main shaft of a surgical tool (not shown), such as an acetabular cup inserter used in hip arthroplasty. The tracker instrument provides an optically trackable target **110** similar to FIG. **1** in the form of a pattern of reflective spheres. The tracker instrument is a rigid body, meaning that under expected forces during use, storage or processing, the tracker instrument does not deflect mechanically. That is, it does not deflect sufficiently that the trackable target remains accurate for tracking relative to the two or more interfaces.

The tracker instrument **200** as shown in FIG. **2** may have mechanical interfaces at opposite ends with the interfaces pointing approximately 180° (plus or minus 25°) away from each other. For example, the probe tip **112** may be at a first end **202** of the tracker instrument **200**, and a V-channel tool interface **204** may be at a second end **206** of the tracker instrument **200**. The optically trackable target may be located between both ends. The advantage of having mechanical interfaces at opposite ends of the tracker instrument is that there is a lower likelihood that the other interface will interfere with the interface being used for coupling.

FIG. **3** is an illustration of components of a surgical navigation system **220** including a tracker instrument **200** in accordance with FIG. **2**. A computing unit (not shown) may determine the pose (in up to 6 degrees of freedom) of the two or more mechanical interfaces by receiving tracking signals of the tracker instrument, calculating pose information of the tracker instrument based on the tracking signals, and determining the pose of the two or more mechanical interfaces based on the pose information. The computing unit may access calibration data defining the positional relationship between the trackable element of the tracker instrument and the respective mechanical interfaces to determine the mechanical interfaces' respective pose(s). These poses may be computed simultaneously or successively.

In the context of an optical localization system, the computing unit may determine the pose (in up to 6 degrees of freedom) of the two or more mechanical interfaces by receiving optical information of the optically trackable target of the tracker instrument from a camera, calculating pose information of the tracker instrument based on the optical information, and determine the pose of the two or more mechanical interfaces based on the pose information. The computing unit may access calibration data defining the positional relationship between the optically trackable target and the mechanical interfaces to determine the mechanical interfaces' respective pose(s).

Calibration data defines the positional relationship between the trackable element (e.g. the optically trackable target of an optical localization system, or an electromagnetic probe of an electromagnetic localization system) and the mechanical interfaces. The calibration data may be pre-loaded onto memory of the computing unit based on the manufacturing specifications of the tracker instrument (i.e. each tracker instrument is consistently manufactured). Alternatively, a calibration routine may be required before use, in which calibration pose data is received by a computing unit, and calibration computations are performed. For example, to determine calibration data of the tip of a probe, the tracker instrument may be pivoted about the tip, while the computing unit receives tracking signals, determines calibration pose data representing various poses during the pivoting, and computes calibration data by executing a center-of-rotation calculation based on calibration pose data.

The same tracker instrument may be used for spatial measurements of two or more features (e.g. an anatomical landmark and a surgical tool). The computing unit may determine navigation context information that represents usage of the tracker instrument at a given point during the surgery. The navigation context information identifies which mechanical interface is relevant at that moment. For example, with reference to the tracker instrument of FIG. **2** when probing anatomical landmarks, it is the probe tip that is relevant, while the tool interface (e.g. V-channel) is not relevant. The navigation context information indicates which mechanical interface is relevant at a given moment. The navigation context information may be determined in part by the pose of the tracker instrument. If the tracker instrument is oriented with the probe tip pointing downwards (and consequently the V-channel pointing upwards), the computing unit may implement a heuristic to determine that the probe tip is the currently active mechanical interface (the heuristic being based on the fact that it is unfeasible to have the V-channel pointing upwards during use).

If the computing unit is executing a software workflow, the navigation context information may be determined by the computing unit based on what step is being executed within the workflow. For example, when the current step of the software workflow corresponds to a surgical step involving the alignment of a surgical tool, the navigation context

information would identify the V-channel (as opposed to the probe tip) as the relevant mechanical interface.

The computing unit may use the navigation context information to determine what to do with the navigational information. For example, certain navigational information may be stored in memory of the computing unit, while other navigational information may be provided to a display unit for display to a user. The navigation context information defines the behaviour of the computing unit with regard to how the navigational information is provided.

The surgical localization system **220** comprising a tracker instrument **200** may be used by a surgeon performing total hip arthroplasty in accordance with the following exemplary method:

A reference element of the localization system is attached to the patient's pelvis, the reference element being rigidly coupled to the pelvis, the localization system being configured to measure relative pose between the tracker instrument and the reference element (e.g. the reference element may be a camera attached to the pelvis as shown in FIG. **3**).

The patient's pelvis may be registered to the localization system by performing an anatomical registration method including contacting multiple prescribed anatomical landmarks on the pelvis using the probe tip of the tracker instrument. A computing unit of the localization system determines the position of the tip of the tracker instrument when in contact with each respective landmark, and performs registration computations to determine the registration between the reference element and the patient's pelvis.

The hip joint is exposed.

Prior to dislocation of the femoral head, the baseline (i.e. prior to arthroplasty) position of a landmark on the femur is determined by the computing unit when the surgeon contacts the landmark with the probe tip of the tracker instrument.

After dislocation and acetabular preparation, the acetabular cup is coupled to an acetabular cup inserter for insertion into the prepared acetabulum.

The surgeon couples the tracker instrument to the acetabular inserter **400** (as illustrated in FIG. **4**) so that the V-channel is axially aligned with the axis of the acetabular inserter. When coupled, the computing unit of the localization system determines the orientation of the acetabular cup and provides this information to a display unit; the surgeon views the display unit and uses the information to adjust, select and/or fine tune the orientation of the acetabular cup prior to impacting it in place.

The surgeon prepares the femur and reduces the prosthetic joint.

The post-reduction (i.e. after arthroplasty) position of the landmark on the femur is determined by the computing unit when the surgeon contacts the landmark with the probe tip of the tracker instrument. The computing unit further determines change in leg position based on the spatial difference between pre-dislocation and post-reduction femur landmark positions.

In general, the surgeon (or any other user) may invoke the computing unit to receive tracking data (e.g. from reference element **102**) when the probe (or any mechanical interface) is coupled to its respective object (e.g. anatomical landmark, surgical tool), via button presses, voice commands, foot pedals, etc. Reference element **102** may comprise one or more buttons **402**.

The mechanical interfaces of the tracker instrument depend on the type of surgery, including the type of existing surgical tools to which the tracker instrument must interface to facilitate clinically relevant navigational information. A V-channel is well suited for measuring orientation of an axis.

In total knee arthroplasty, navigational information about the alignment of planes is important, and knee instrumentation provides planar cutting slots that guide planar bone cuts by an oscillating saw. A tracker instrument **500**, as shown in FIG. **5**, provides two mechanical interfaces: a probe tip **112** and, separately, a planar feature **502** comprising the tool interface. The planar feature comprises at least one planar surface and in the present example, two opposing planar surfaces, for example, to interface with a cut slot of a knee cutting jig (not shown) used for TKA. The tool interface may include a magnet (not shown) configured to engage the planar feature with a portion of a tool. For example, when the planar feature is engaged with the (ferrous) cut slot, a magnetic force keeps the tool and slot engaged without the need for a user to hold them together. Furthermore, as the planar feature may not be sized for a perfect fit within the slot, the magnetic force may ensure that a plane of the planar feature is fully seated on the desired surface of the cut slot.

A surgical localization system such as system **220** comprising such a tracker instrument **500** may be used by a surgeon performing total knee arthroplasty in accordance with the following exemplary method:

A reference element of the localization system is attached to the patient's femur, the reference element being rigidly coupled to the femur, the localization system being configured to measure relative pose between the tracker instrument and the reference element (e.g. the reference element may be another tracker rigidly fixed to the femur).

The knee joint is exposed.

The patient's femur may be registered to the localization system by performing an anatomical registration method defining at least one anatomical axis including contacting multiple prescribed anatomical landmarks on the femur **600** using the probe tip **112** of the tracker instrument **500** (as illustrated in FIG. **6**, where the probe tip is shown contacting the femoral epicondyle **602**) and/or articulating the hip joint about its hip center of rotation **604** while the reference element is tracked by the localization system. A computing unit of the localization system performs registration computations based on probe tip and/or center of rotation data to determine the registration between the reference element and the patient's femur. The femur registration may be navigational information that is saved in computer memory.

The patient's tibia may be registered to the localization system by performing an anatomical registration method defining at least one anatomical axis including contacting multiple prescribed anatomical landmarks on the femur using the probe tip of the tracker instrument. A computing unit of the localization system performs registration computations based on probe tip data to determine the registration between the reference element and the patient's tibia. The tibia registration may be navigational information that is saved in computer memory.

The planar feature of the tracker instrument is coupled with the cutting slot of a femoral cutting jig. FIG. **7** is a CAD illustration showing the planar feature in an alignment with the femur (note: the cutting jig is not shown for clarity).

The cutting jig is fixed into alignment with the femur based on navigational information provided on a display comprising the orientation of the cutting plane relative to the femur as defined by the femur registration, the navigational information based on the calculated pose of the planar feature.

The femur is cut, and the cutting jig is removed.

The planar feature of the tracker instrument is coupled with the cutting slot of a tibial cutting jig.

The cutting jig is fixed into alignment with the tibia based on navigational information provided on a display comprising the orientation of the cutting plane relative to the tibia as defined by the tibia registration, the navigational information based on the calculated pose of the planar feature.

The tibia is cut, and the cutting jig is removed.

The tibia and femur are fitted with implants, and the joint is reduced.

FIG. **8** is an annotated CAD illustration of a tracker instrument **800**, in which one mechanical interface is a kinematic mount **802** that is repeatable in 6 degrees of freedom (i.e. when coupled to a mating kinematic mount, the position and orientation of the tracker instrument is fully constrained). The other mechanical interface is the tip of a probe **112**. FIG. **9** is an annotated CAD illustration showing details of exemplary kinematic mount **802**, in which three partly spherical features **902** and three magnet locations **904** are shown (note: magnets not shown). A mating kinematic mount has three slots and three magnets corresponding to the kinematic mount shown, such that the magnets impart a holding force keeping both sides of the mount engaged with the three partly spherical features contacting the three slots.

FIG. **10** is an annotated CAD illustration of a tracker instrument **1000**, in which one mechanical interface is a planar feature **1002**, having a planar surface **1004** cylindrical in shape, which is oriented transverse to the longitudinal axis of the tracker instrument. FIG. **11** shows a partial enlarged perspective view of tracker instrument **1000** from the end having the planar feature **1002**, similar to the orientation of FIG. **9** showing the details of the kinematic mount **802**. Planar feature **1002** may also be or include a magnetic base so that the instrument may be magnetically attached to an instrument, etc. The magnetic base may be the entire aspect of the planar feature or there may be a magnet positioned in a center thereof.

Determining calibration data for a tracker instrument **200** having a probe tip is described earlier herein where one method describes receiving previously stored calibration data and a second method describes generating such data by pivoting the instrument about the probe tip during a calibration routine. In a similar manner, calibration data may be received for a tracker instrument having a planar feature. There may be an analogous calibration routine by which to determine calibration data of the planar feature. For example, a user may "paint" a flat surface with the planar feature.

The complexity of a system for performing a navigated surgical procedure comprising a tracker instrument as described herein may be greatly reduced. For example, the number of components required to perform surgical navigation may be reduced to: one tracker instrument; one tracking system (comprising a computing unit in communication with a tracking sensor such as a camera); and one reference element. Additionally, system components may have a simplified use, since the system may require fewer steps for assembly and interfacing (e.g. no need for dedicated adaptors).

In particular, the usage of the components within the sterile field may be simplified (i.e. the reference element and the tracker instrument). In one implementation, the tracker instrument is pre-sterilized and single-use (disposable). Tracker instruments may be packaged in multiple layers of protective packaging to ensure sterility, shelf life and physical integrity. A new tracker instrument may be used for each surgical procedure, and the tracker instrument not require any pre-operative assembly, such as attachment of reflective spheres onto a reusable tracker.

Hospital reprocessing/sterilization (e.g. autoclaving) is costly and introduces logistical complexities when multiple surgical procedures are occurring in a single day, since there is limited time to reprocess tools/instruments/equipment. Additionally, when new equipment is brought into the hospital, it must be brought in before surgery, to allow for ample time for reprocessing, which typically occurs overnight. Eliminating the need for hospital reprocessing is desirable. In one implementation, the navigation system described herein does not require the reprocessing of any components:

the tracker instrument is pre-sterilized, single-use and disposable,

the reference element is either pre-sterilized, single-use and disposable or is reusable and enclosed within a sterile barrier that is itself a pre-sterilized, single-use and disposable (such as a camera drape providing a clear window for transmission of optical signals, where the reference element is a reusable camera),

the reference element fixation components (e.g. bone screws, camera clamp) are pre-sterilized single-use and disposable.

The elimination of the need for hospital reprocessing is enabled by the reduction in number and simplification of system components within the sterile field. Without the reduction in number of sterile components, disposal would be prohibitively costly and raise significant environmental concerns. Many hospitals have strict disposal and waste policies, such that only a small quantity of waste may be tolerated per procedure. Therefore, a requirement for a navigation system based on pre-sterilized, single-use and disposable components (instead of hospital-based reprocessing) is low waste generation.

FIG. **12** is a flowchart illustrating a method **1200** to perform a navigated surgical procedure. At step **1202**, the method comprises contacting at least one anatomical landmark with a tip of an instrument comprising an optically trackable target, a tool interface and the tip. At step **1204**, a computing unit is invoked to execute instructions to: receive from a camera first optical information of the optically trackable target when the tip is in contact with the anatomical landmark; calculate a first pose of the instrument based on the first optical information; determine a position of the tip based on the first pose of the instrument; and determine first navigational information based on the position of the tip. At step **1206**, the method **1200** comprises coupling the instrument with a surgical tool via the tool interface.

At step **1208**, the method **1200** comprises invoking the computing unit to execute instructions to: with the instrument coupled to the surgical tool, receive second optical information from the camera of the optically trackable target; calculate a second pose of the instrument based on the second optical information; determine a pose of the tool interface based on the second pose of the instrument; and determine second navigational information based on the pose of the tool interface. The method **1200** comprises, at step **1210**, receiving by viewing a display screen the first and/or second navigational information. The first and/or second navigational information may be provided to the display screen by the computing unit based on navigation context information. The computing unit may determine the navigation context information, for example, at least in part based on a pose of the tool interface and/or a pose of the tip.

The method **1200** may further comprise a step (not shown) of adjusting or confirming spatial attributes related to the surgical procedure based on the received navigational information.

FIG. **13** is a flowchart showing a computer implemented method **1300** to perform a navigated surgical procedure. The method **1300** comprises, at step **1302**: receiving, by a computing unit from a camera, first optical information of the optically trackable target, the optically trackable target comprising a component of an instrument, the instrument further comprising, separately, a tool interface and a tip, and wherein the first optical information are received when the tip is in contact with an anatomical landmark. At step **1304**, the method **1300** comprises calculating by the computing unit a first pose of the instrument based on the first optical information and, at step **1306**, determining by the computing unit a position of the tip based on the pose of the instrument. At step **1308**, the method **1300** comprises determining first navigational information based on the position of the tip. At step **1310**, the method comprises receiving, by the computing unit from the camera, second optical information of the optically trackable target when the instrument is coupled to a surgical tool via the tool interface, and, at step **1312**, calculating by the computing unit a second pose of the instrument based on the second optical information. There is determined, by the computing unit, a pose of the tool interface based on the second pose of the instrument at step **1314**; and, at step **1316**, second navigational information based on the pose of the tool interface. At step **1318** the method **1300** comprises providing by the computing unit to a display screen the first and/or second navigational information.

In method **1300**, the first and/or second navigational information may be provided to the display screen by the computing unit based on navigation context information. It will be understood that first navigational information may be determined and provided before any second navigational information is determined and/or provided and vice versa. The reference to "first" and "second" is disambiguate the navigation information and not a reference to an order of operations. The reference to receiving optical information from the camera should not be limited to only receiving a single instance of such information. For example, first optical information may be received at one instance in time and used to determine the first navigational information based on the position of the tip at that instance in time. Some optical information may be received at a second instance of time and used to determine the second navigational information. Again, the first and second instances do not require an order of occurrence in real time.

The computing unit described herein may comprise a laptop, workstation or other computer having one or more processors (e.g. microprocessors), storage devices (e.g. RAM, ROM or other memory device, removable devices), communication devices, buses, input devices, output devices and/or I/O devices such as keyboard, buttons, foot pedal, pointing device, microphone, speaker, lights, bell, display screen (which may be touch or gesture enabled), etc. and these may be on-board or coupled thereto via communication interfaces and/or buses. Communication interfaces and communication devices may couple the computing unit in a wired or wireless manner to one or more networks or to input, output and/or I/O devices. Software (e.g. instructions stored in memory) may provide components for configuring the computing unit when the software is executed by the one or more processors. The various clinical applications and tracking modalities referred to in this description are meant to be exemplary and non-limiting.

What is claimed is:

1. A surgical instrument comprising:
a probe tip for probing positions in a space;
a tool interface, separate from the tip; and
an optically trackable target;
wherein the optically trackable target is configured to provide optical information with which to determine the positions;
wherein the tool interface is configured to mate with a surgical tool such that the optical trackable target then provides optical information with which to determine positional information for the surgical tool in the space; and
wherein the tool interface comprises channel surfaces defining a channel having a V-shape, the channel surfaces configured to receive a shaft of the tool for coupling the instrument to the surgical tool.

2. The surgical instrument of claim **1**, wherein the tip and the tool interface are located at opposite ends of the instrument.

3. The surgical instrument of claim **2**, wherein the optically trackable target is located between the opposite ends.

4. The surgical instrument of claim **2**, wherein:
the instrument defines a rigid body between the opposite ends; and
the probe tip is positioned at one of the opposite ends, along a longitudinal axis of the rigid body, extended away from the tool interface.

5. The surgical instrument of claim **4**, wherein the rigid body comprises a rigid rod, the probe tip located at a free end of the rigid rod, the free end defining one of the opposite ends of the instrument.

6. The surgical instrument of claim **2**, wherein:
the instrument defines a rigid body between the opposite ends; and
the tool interface is positioned at a free end of an extension member of the rigid body, away from the probe tip.

7. The surgical instrument of claim **1**, wherein the instrument is pre-sterilized, single-use and disposable.

8. A method comprising:
probing a position in a space using a probe tip of a surgical instrument, the probing providing optical information, associated with the position, to a system for navigational information, the instrument comprising:
the probe tip for probing positions in the space;
a tool interface configured to mate with a surgical tool, the tool interface separate from the tip; and
an optically trackable target configured to provide the optical information to the system;
coupling the surgical instrument via the tool interface to the surgical tool wherein the tool interface comprises channel surfaces defining a channel having a V-shape, the channel surfaces configured to receive a shaft of the tool for coupling the instrument to the surgical tool;
using the tool with the surgical instrument coupled thereto to provide optical information, associated with the surgical tool in the space, to the system for determining positional information for the surgical tool;
receiving navigational information responsive to the position and the positional information for the surgical tool.

9. The method of claim **8** comprising: receiving, from the system, first navigational information based on at least one position probed by the probe tip.

10. The method of claim **9** comprising: receiving, from the system, second navigational information associated with a pose of the tool interface, the pose determined from the optical information received when the tool is coupled to the tool interface.

11. The method of claim 10 comprising orienting a pose of the surgical instrument to signal navigational context information to the system to indicate which of the first navigational information and the second navigational information is to be received from the system.

12. The method of claim 8, wherein steps of the method are performed in association with workflow of the system.

13. The method of claim 8, wherein the method is performed during a hip arthroplasty surgery on a patient and the navigational information comprises leg position change information and acetabular implant alignment information.

14. A method comprising:

probing a position in a space using a probe tip of a surgical instrument, the probing providing optical information, associated with the position, to a system for navigational information, the instrument comprising:

the probe tip for probing positions in the space;

a tool interface configured to mate with a surgical tool, the tool interface separate from the tip; and

an optically trackable target configured to provide the optical information to the system;

coupling the surgical instrument via the tool interface to the surgical tool;

using the tool with the surgical instrument coupled thereto to provide optical information, associated with the surgical tool in the space, to the system for determining positional information for the surgical tool;

receiving navigational information responsive to the position and the positional information for the surgical tool;

wherein the method is performed during a hip arthroplasty surgery on a patient and the navigational information comprises leg position change information and acetabular implant alignment information; and

wherein:

the tool comprises an acetabular implant inserter tool;

the tool interface comprises a V-channel to mate with an axis of the tool;

the step of probing a position comprises probing a first position to provide first optical information to the system for the first position, the first position comprising a landmark on a patient's femur in contact with the probe tip, prior to arthroplasty;

the step of using the tool comprises performing an acetabular implant alignment; and

the method comprises:

further probing a second position to provide second optical information to the system for the second position, the second position comprising the landmark on a patient's femur in contact with the probe tip, after arthroplasty;

receiving from the system the change in leg position information based on at least the first position and second position; and

receiving the acetabular implant alignment information from the system based on at least a pose of the tool interface when coupled to the tool during the acetabular implant alignment.

15. The method of claim 14, wherein:

the instrument is pre-sterilized, single-use and disposable;

the system comprises a camera; and

the method comprises draping the camera with a drape configured to provide a sterile barrier around the camera, the drape further comprising an optical window to enable the camera to generate the optical information from within the sterile barrier.

16. The method of claim 14 comprising disposing of the instrument following completion of a single surgical procedure.

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